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Access to Infrastructure and Human Development: Cross-Country Evidence

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Cross-Country Evidence

Jeet Bahadur Sapkota*

Abstract

Despite extensive policy discussion, limited empirical literature is available concerning the impacts of infrastructure on human development. Furthermore, major infrastructure services, such as transport and energy, are missing in the current Millenium Development Goals (MDGs) framework; although there is a firm consensus that infrastructure is the main vehicle in achieving MDGs. Therefore this study assesses the impacts of several infrastructure variables (access to electricity, access to clean drinking water sources, and road density) on the human development index (HDI) and its three component indexes (i.e., health, education, and income), using the panel data of 1995 to 2010 covering 91 developing countries. Dynamic panel estimation of General Methods of Moments resulted in revealing that all three infrastructure variables have significant positive impacts on HDI. However, access to electricity and access to clean drinking-water sources have positive and significant effects only on education and health indexes. On the other hand, road density is highly significant to increase the income index. Thus it is argued that eradication of all forms of infrastructure poverty (defined as "lack of access to infrastructure services") is a necessary condition to eliminate human poverty sustainably. Thus it is essentially important to address the infrastructure poverty comprehensively in post-2015 new-development strategies.

Keywords: human development, infrastructure poverty, post-2015 development strategies, panel data

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1. Introduction

Well-established evidence of significant impacts of infrastructure on economic growth is available (for a detailed survey of the literature, see World Bank 1994 and Samli 2011). However, the general approach to development has changed dramatically in recent decades from economic concentration to human focus (Todaro and Smith 2012). Quite extensive discussions are found on the impact and importance of infrastructure on human development because a lack of access to basic infrastructure services undermines the inclusive development (Tanaka 2012; JICA 2004; Fujita, Tsuruga, and Takeda 2013). Lack of access to basic infrastructure services itself can be defined as "infrastructure poverty" because without such access, it is extremely difficult to fulfill basic human needs. Admittedly there is a question of affordability and capability of utilizing the services (Hosono 2012); however, having access is the prime necessity (for a detailed discussion on access and affordability, see Briceno-Garmendia et al. 2004). Despite extensive policy discussion, limited empirical literature is found on the subject matter, especially on the impact infrastructure variables on human development (Kusharjantoa and Kim 2011). We are unaware of any such empirical work in a cross-country setting; therefore this is the first attempt to narrow this gap by exploring the impacts of three main infrastructure variables, namely, access to electricity, clean drinking water, and road networks on the human development index (HDI) and its components in developing countries.

Such an exploration is urgently essential because despite being one of the main vehicles in meeting the Millennium Development Goals (MDGs) (Scout and Seth 2012), infrastructures, especially transportation and energy, are missing from the MDGs framework. Some of the donor agencies, such as Japan International Cooperation Agency (JICA), highly emphasized the importance of infrastructure in achieving the MDGs inclusively and took the infrastructure

development as one of the key approaches to support the MDGs process (JICA 2010:11).[1] Thus the paper empirically tests the impacts of the three key infrastructure variables, i.e., access to electricity, access to clean drinking water sources, and road density, on improving the overall human development index (HDI) and its component indexes.

This paper is organized into five sections. Section 2 reviews the relevant literature and develops a dialectic model that presents the impact channels of infrastructure and human development. Section 3 describes the data and methodology, and section 4 presents the results showing the significant impacts of infrastructure on human development. Section 6 concludes the paper with the argument that access to basic infrastructure services would be one of the main vehicles to achieve human development goals; hence infrastructure access should be incorporated into the new international development strategies.

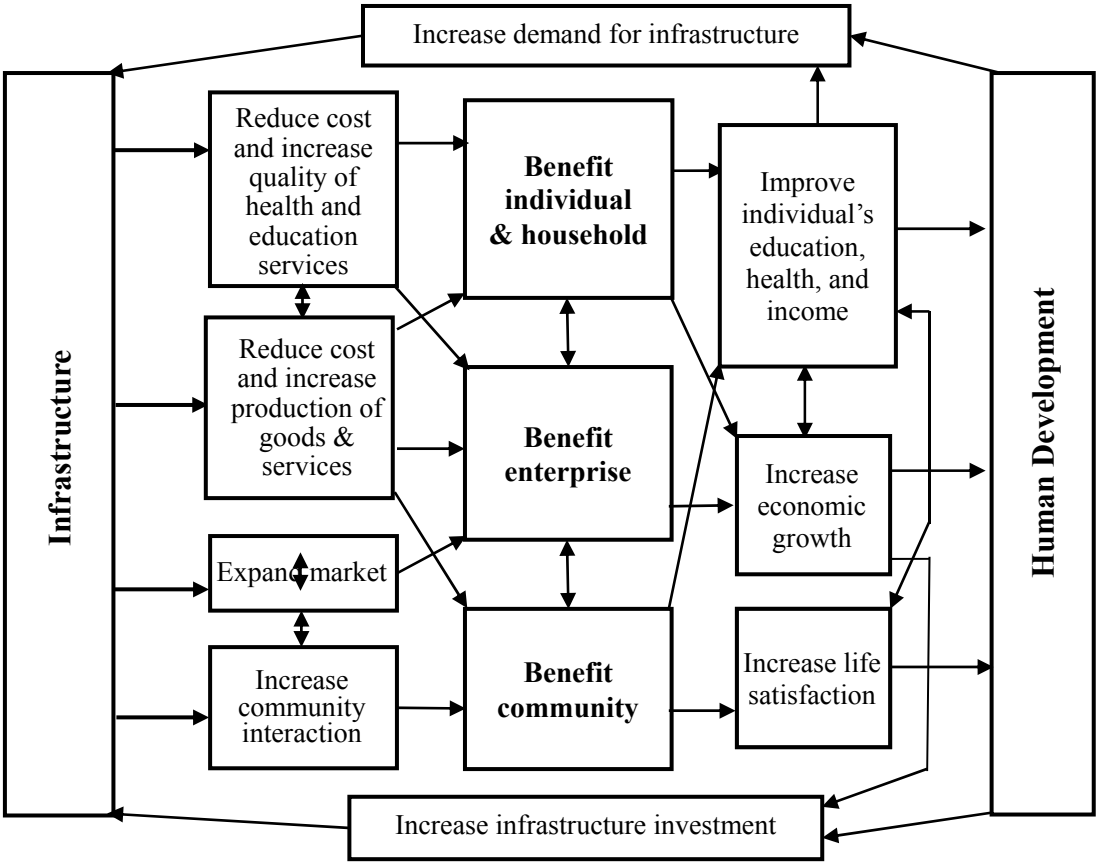
2. Impact channels of infrastructure and human development

Based on the existing literature, Fig. 1 presents a dialectic model of infrastructure and human development. The arrow of the lines shows the direction of the flow of impact; thus the lines with arrows at both ends indicate that the impacts flow both ways. The figure shows the multiple channels through which the links operate between infrastructure and human development. There is a firm consensus that the increased access to infrastructure services, such as energy, water, and transportation, directly benefits individuals and households, communities, and companies (World Bank 1994). It benefits individuals and households by reducing cost and increasing quality of health and education services that further help to improve the education and health of an individual, which ultimately increase the level of human development at local and national levels. For example, rural infrastructures increase the household and individual welfare by

1. In its policy document "JICA's Approach to the Millennium Development Goals: For inclusive and dynamic development," JICA listed infrastructure as one of the three major approaches to support the MDGs. The other two approaches are human security and capacity development.

improving farm and nonfarm productivity, thus raising the level of income and consumption, reducing private costs, and saving time (WHO/UNICEF 2008; Ezcurra et al. 2005; Ali and Pernia 2003). Such effects clearly lead to an improved level of human development. Access to infrastructure not only provides direct benefits by reducing the prices of manufacturing goods (Khandker et al. 2009) but it also indirectly generates new opportunities, such as employment generation (Gachassin et al. 2010; Jacobs and Greaves 2003), market expansion, and integration (Bhattacharyay 2012; World Bank 1994). A significant positive impact of infrastructure on health and education is also firmly established in the literature (Khandker et al. 2009; Bryceson and Howe 1993; Levy 1996). Interestingly, literature suggests that rural infrastructure improves the education and health of women and girls more significantly than it does of males (Levy 1996; Bryceson and Howe 1993).

Figure 1: A dialectic model of infrastructure and human development



Source: The author

Similarly, communities can benefit through increased interactions with group members and also through its increased size (Hurlin 2006), which helps to increase the level of satisfaction, one of the psychological factors of human development. OECD (2002) claims that apart from generating employment and boosting efficiency, infrastructure helps social inclusion through increased social mobility and preserves environment through the efficient use of natural resources. Their arguments are supported with several case studies. For example, Kirubi et al. (2009) showed the significant contribution of community-based electric microgrids on rural development through community development in Kenya. Interestingly, sectoral studies focusing on the rural infrastructure by the World Bank (2004) revealed that infrastructure benefit is higher in less-developed communities than in more-developed ones because increased access to market and banking services, increased communication, and a reduced cost of doing business are usually more evident in less-developed communities.

Lastly, increased infrastructure services directly benefit business enterprises through expanded market opportunities, reduced cost of production, and increased production quality and volume of goods and services (Jacoby 2002). Literature suggests that rural community-based infrastructure, such as rural roads, rural small-scale electrification, and water supply and irrigation projects, significantly benefit small- and medium-scale enterprises by increasing land and labor productivity, improving the community's health and education levels, enhancing banking and communication services, and helping to commercialize agriculture (Kirubi et al. 2009; Khandker, Bakht, and Koolwal 2009; Mu and van de Walle 2007; Lokshin and Yemtsov 2005; Jalan and Ravallion 2003; Reinikka and Svensson 2002). These all increase the rate of economic growth and ultimately contribute to human development (World Bank 1994).

On the other hand, while individuals' education, health, and income levels rise, they create further demands for infrastructure services. Similarly, increased economic growth rate also helps to increase the quality and quantity of infrastructure services through increased

investment in infrastructure development (Bhattacharya 2012). Therefore infrastructure variables are not purely exogenous rather than endogenous to human development. This issue is addressed in the method of empirical assessment in the following section.

3. Data and methodology

3.1 The data

3.1.1 Dependent variables

Human development is the dependent variable. To measure a country's level of overall human development, we use the human development index (HDI), which was developed by the United Nations Development Program (UNDP) in 1990, aiming to provide a yardstick of human development of all member countries of the United Nations. The focus was on people, as the opening lines of the first HDI publication states:

> The real wealth of a nation is its people. And the purpose of development is to create an enabling environment for people to enjoy long, healthy and creative lives. This simple but powerful truth is too often forgotten in the pursuit of material and financial wealth. (UNDP, 1990:1)

The UNDP has been publishing the annual Human Development Report (HDR) for the world and occasionally for regions and member states since 1990. The HDR's basic principle is that the essential components of quality of life are the combination of a long and healthy life, education, and a decent standard of living. As a result, the HDI has measured human development through the use of three factors; longevity, knowledge, and GDP per capita measured in purchasing power parity (PPP).

Thus we used HDI and its component indexes as a dependent variable because its principles are reflected in the MDGs framework as it also sets health- and education-related goals together with income or poverty goals. See the technical notes of HDR 2011 for details on

how the HDI and its components are calculated.[2] In brief, the health aspect is measured through life expectancy at birth and converted into the Health (or life expectancy) Index (HI), using a minimum value of 20 years and observed maximum value over 1980-2010. The Education Index (EI) is calculated using the population's mean years of schooling (of adults) and expected years of schooling (of children). The Income (or Gross National Income [GNI]) Index (II) is based on the GNI per capita (2005 PPP International $, using the natural logarithm) expressed as an index using a minimum value of $100 and observed maximum value over 1980-2011. The data of these dependent variables are taken from the HDI database of the UNDP.[3] As the HDI trend data are available in five-year intervals until 2005, we used the panel data of 1995, 2000, 2005, and 2010. The analysis is limited to 91 developing countries because of the limited data availability for some independent variables. The names of countries covered in the analysis are listed in Appendix 1.

3.1.2 Explanatory variables

Infrastructure variables are the main explanatory variables of this study. According to the **Economic and Social Commission for Asia and the Pacific** (ESCAP) and Asian Institute of Transport Development AITD (2003), infrastructure is defined as the physical facilities, such as roads, airports, utility supply systems, and communications systems, together with services generating from these facilities; such as water, sanitation, transportation, and energy. Although a large number of the developing world's population has been gaining access to infrastructure services in recent decades, large numbers of people remain without access to basic infrastructure services that hinder their overall development.

For example, approximately 2 billion people gained access to electricity (GEA 2012) and clean drinking water (United Nations 2012) from 1990 to 2008. On the other hand, if

2. The technical notes can be accessed at: http://hdr.undp.org/en/media/HDR_2011_EN_TechNotes.pdf
3. The HDI database can be accessed at http://hdrstats.undp.org/en/tables/

the current trend follows, by the end of the next 15-year period of international development goals, the numbers without access will be just as large as they are today. This continued lack of access will quite likely retard the achievement of any development goals agreed for the post-2015 period.

Therefore the following three main infrastructure indicators are the main explanatory variables of this study. First, we use "access to electricity as the percentage of the population." Its data are taken from the World Bank's world development indicators (WDI) online database.[4] The literature suggests that increasing access to electricity improves the human aspects of development through increased time for study by girls and boys in a rural area, saving time for fuel-wood collection, increasing household income, and reducing poverty (Khandker et al. 2012, 13-14) that ultimately uplift the level of human development. A wide consensus among scholars believes that providing access to electricity and other modern sources of energy substantially contributes to increasing household welfare (e.g., ADB 2010; World Bank 2008; Cockburn 2005).

Second, we apply "proportion of the population using improved drinking water sources." Its data are taken from the UN Statistics MDGs Indicators database.[5] It defines the improved water sources as a household connection, public standpipe, borehole, protected well or spring, and rainwater collection. Literature shows that water is itself an economically productive asset, and sound water infrastructure is significant in improving the health and livelihood of humans (Cleaver et al. 2005; Joshi 2004; Slaymaker et al. 2007). The human development impact of increasing access to clean drinking water also channels through time savings, which could reduce the burden on women and girls in rural areas who ultimately lead their productivity (Slaymaker et al. 2007).

4. The World Bank's WDI database is one of the most comprehensive and up-to-date databases of development publicly available and can be accessed freely at http://databank.worldbank.org/data/home.aspx
5. The database can be accessed at: http://unstats.un.org/unsd/mdg/Data.aspx

Lastly, we used access to road, which is proxy by the "road density in terms of kilometers of road network per 100 sq. km of land area," and the data are taken from the WDI database. It defines road network as all roads in the country including motorways, highways, main or national roads, secondary or regional roads, and other urban and rural roads. Many scholars claimed that transport infrastructure has a higher impact than any other kind of infrastructure on economic growth, productivity, and even on poverty reduction (Sakamoto et al. 2010; Hook and Howe 2005; Ellis 1997). However, not many studies analyze the contribution of transport to the MDGs achievement (Estache and Fay 2007; Hook and Howe 2005; Estache 2004), and there are no transport-related issues within the MDGs framework.

We use four control variables that also potentially affect human development significantly. First, the consumer price index (2005 = 100) is taken as increasing the prices of daily consumption goods that always hit low-income families, whose health is thus adversely affected (World Bank 2012). Second, we control for population growth (annual percent) because of a large body of literature on the linkages between population dynamics and development, and population growth is always considered a negative factor of human development (Lee 2001; Egunjobi 1991).

A vast body of literature also exists on development impacts of globalization (for a detailed review of the literature, see Sapkota 2011); thus we control also for the level of globalization of the countries. This study uses the *Konjunkturforschungsstelle* (KOF) index of globalization because of its comprehensiveness and data availability. The KOF index of globalization was introduced by Dreher (2006). Following the explanations of Clark (2000), Norris (2000), and Keohane and Nye (2000:4), Dreher defined globalization comprehensively as follows:

> Globalization is meant to describe the process of creating networks of connections among actors at multi-continental distances, mediated through a variety of flows including people, information and ideas, capital and goods. Globalization is conceptualized as a process that erodes national boundaries, integrates national economies, cultures, technologies and

governance and produces complex relations of mutual interdependence (Dreher 2006, 1092).

Based on this comprehensive definition, he systematically constructed the KOF index of globalization, which measures the economic, social, and political dimensions of globalization covering 24 variables over time. The data, updated annually, are available for 207 countries from 1970 to 2010 on an annual basis.[6]

Lastly, a *democracy index* is used to control the effect of the level of freedom in a country on human development. Theoretical linkages of freedom and human development are well discussed in the literature after the Nobel Laureate Amartya Sen (1999) published his remarkable book, *Freedom as Development*, and democracy is considered one of the significant predictors of human development. For a detailed survey of the literature, see Gerring, Thacker, and Alfaro (2012). The data of democracy index are taken from the Freedom House, which consists of two key rights.[7] First, the political rights measure is a subjective indicator that annually ranks each country on a scale from one (the highest level of political rights) to seven (the lowest level). Second, the civil liberty measure is used to capture personal rights, such as free to express, organize, or demonstrate and is placed on the same scale from one to seven. These two measures of Freedom House are averaged as the overall democracy index.

All independent variables are taken as the most recent five-year average unless specified otherwise. For example, data of year 2010 are the annual average of data for 2006 to 2010. This allows us to use those variables that have no data on a regular basis (in fact, most variables have no data for the some years). The average of the past 5 years also justifies the argument that the impact of the infrastructure of other independent variables on human development is less

6. Further details of the KOF index, its methodology, and the data are available at http://globalization.kof.ethz.ch/.
7. "Freedom House is an independent watchdog organization dedicated to the expansion of freedom around the world," and the data and definition are available at http://www.freedomhouse.org/.

instantaneous and more gradual. The summary of statistics and the correlation matrix of the variables are presented in Appendixes 2 and 3.

3.2 Model specifications

To assess the impacts of infrastructure on human development, we employed the dynamic panel data model implemented by Kusharjantoa and Kim (2011) with some improvement. They simply regressed some infrastructure variables with the HDI and its component variables of the respective regencies within Java Island of Indonesia. However, we used HDI and its component indexes to make each regression consistent with each other. Because the panel data is of cross-country, the specification of each regression equation is desirable to change, and the data availability of the component variables are less consistent than the component indexes across countries. Furthermore, we need to control for some country-specific characteristics to minimize the biases that spur from country-specific characteristics. Therefore we control for some country-specific characteristics introducing control variables. We also control for the income group of countries through the income dummy. Thus the regression model is specified as follows:

$$Y_{it} = \alpha + \beta_1 Y_{it-1} + \beta_2 INFRA_{it} + \beta_3 C_{it} + \eta_i + \eta_t + \varepsilon_{it}$$

Where Y_{it} represents the dependent variables (i.e., HDI, EI, HI, and II as explained in Section 2.1) of country i at year t, Y_{it-1} is one period lag of the dependent variable, $INFRA_{it}$ represents the infrastructure-related variables, C_{it} represents the vector of control variables, η_i is the country-fixed effect, η_t is the time-varying effect, and ε_{it} is an error term. Each variable and the respective hypotheses are explained in the previous Section 3.1. The constant term is α, and β_1, β_2, and β_3 are the coefficients of each explanatory variable, which are the parameters of interest.

The lagged dependent variable is included in the set of explanatory variables because human development indicators tend to change slowly over time. This creates the dynamic structure of the model, which allows distinguishing between the short-term and long-term effects of the independent variables. The coefficient on the lagged dependent variable β1 represents the speed of adjustment. Static models assume that this parameter is equal to zero.[8] The long-term effects of an independent variable can be estimated by dividing the parameter of the independent variable by one minus the parameter of the lagged dependent variable (Greene 2008, 679).

Despite the above benefits, the dynamic structure of the model needs to control for possible biases arising from it (Kurita and Kurosaki 2007). Because given the inclusion of the lagged dependent variable and fixed-country effects, the OLS estimator is biased and inconsistent in short panels (Nickell, 1981). Furthermore, if the infrastructure or other independent variables and the error term "ε_{it}" in the model are not independent, unobserved variables can affect both the outcome variable and independent variable, so the estimated coefficient β_2 and β_3 can be biased. Such problem of endogeneity can be partially solved by controlling fixed effects and time trend, but if some unobserved variable changes over time and across countries, this problem will remain in the error term. To deal with this problem, a dynamic panel data method, especially the system generalized method of moments (GMM) estimator, is used as suggested by Arellano and Bover (1995) and Blundell and Bond (1998). This method is not only appropriate for endogenous independent variables or correlated with past and possibly current realizations of the error term, but also with fixed individual effects (in our situation, the country- specific effect) and heteroskedasticity and autocorrelation within individuals, but not across them (Roodman 2009). Results are based on the two-step estimator implemented by Roodman (2005) with Windmeijer (2005) correction for finite-sample, which is explained in detail by Roodman (2009) in Stata.

8. In a simple equation without a lagged dependent variable, the independent variables capture the complete effects on (a or the?) dependent variable. However, when we include a lagged dependent variable in the equation, its coefficient captured all the effects of the previous history; thus any impact of independent variable represents only the short-run effect. For further explanation, see Greene (2008, 469).

System GMM overcomes the problem of endogeneity by using a potentially large matrix of available instruments and weights them appropriately. However, the inclusion of extra instruments requires additional moment conditions; thus the system GMM builds a system of two equations: the original equation as well as the transformed one.[9]

We include dummies for fragile countries per the "Harmonized List of Fragile Situations FY13," which is a harmonized list of the World Bank, African Development Bank (AfDB), and the Asian Development Bank (ADB). According to the harmonized definition from the World Bank, AfDB, and ADB, "Fragile Situations" are either (a) IDA-eligible countries with a harmonized average CPIA country rating of 3.2 or less (or no CPIA),[10] or (b) the presence of a UN and/or a regional peacekeeping or peace-building mission during the past three years."[11]

Dummies for time periods are included to control time effect and found jointly significant; however, they are excluded from the result table. Similarly, dummies for income groups of countries as specified by the World Bank are also included in the regression to observe the effects on different income groups of countries.

4. Results

We first report the impacts of access to infrastructure on HDI and its component indexes in Table 1, which represents the short-run effects. Column 1 of the table shows the relationship between explanatory variables and HDI, and columns 2, 3, and 4 show the relationships between

9. We assumed that all the independent variables are endogenous except the globalization index, and used as GMM-style instruments in xtabond2 command in Stata, as suggested by Roodman (2009). Similarly, the globalization index and the dummies are used as ivstyle instruments. Because the data structure is panels with gaps, we used an orthogonal deviation to maximize the sample size. The Sargan/Hansen test supports the joint validity of the instruments.
10. IDA is the International Development Association, the World Bank's fund for the poorest countries, and CPIA is the Country Policy and Institutional Assessment, the World Bank's diagnostic tool (rating from 0 to 6) to assess the quality of a country's policies and institutions.
11For the list and a detailed definition of fragile countries, consult http://siteresources.worldbank.org/EXTLICUS/Resources/511777-1269623894864/FCSHarmonizedListFY13.pdf (retrieved 26 February 2013).

explanatory variables and the component indexes of HDI, which include EI, HI, and II. We then report the long-term effect of infrastructure and other independent variables in Table 2.

In Table 1, column 1 shows the positive and significant effects of all infrastructure variables on HDI in developing countries. However, the levels of significance are varied at 1% for access to electricity and 5% for access to improved water sources and road density. The result firmly reconfirms the general claim of JICA (2004, 2010) and other international organizations (e.g., World Bank 1994), as well as scholars (e.g., Kusharjantoa and Kim 2011). All argue that accesses to infrastructure facilities are among the key determinants of human development.

In fact, the lack of access to infrastructure services, which is defined as "infrastructure poverty" in this study, not only hinders the living standards and economic growth, but it also limits human development. It is obvious that the people and communities from the areas where the infrastructure poverty remains high find themselves lagging far behind the MDGs if we replicate these global goals at the local level. Indeed, prevalence of infrastructure poverty is extremely high in many parts of the world. For example, it is estimated that 780 million of the world's population still lack access to clean water sources (UNICEF and WHO 2012). Situation of access to electricity is more serious than the situation of access to clean water sources and road. For instance, the World Bank estimates that "nearly 75 percent of Sub-Saharan Africans, or 550 million people, do not have access to electricity. In South Asia, some 50 percent, or 700 million people, lack access. About 90 percent of those without access in South Asia lives in rural areas."[12] Such lack of access will continue if there are no new appropriate initiatives at either global or local levels, and such infrastructure poverty will significantly hinder the global and local development also after 2015 (Scott and Seth 2012).

12 http://go.worldbank.org/4UU59P0XM0 (retrieved: 6 March 2013)

Table 1: Human development impacts of infrastructure, 1990-2010
Dynamic panel-data estimation, two-step system GMM

	Dependent variables			
	(1)	(2)	(3)	(4)
Independent variables	Human Dev. Index (HDI)	Education Index (EI)	Health Index (HI)	Income Index (II)
Lagged dependent variables	0.34912***	0.57478***	0.19633***	0.43883***
	(0.09351)	(0.09266)	(0.06848)	(0.12288)
Access to electricity (% of population)	0.03240***	0.03544**	0.05328***	0.00592
	(0.01181)	(0.01565)	(0.01853)	(0.01515)
Proportion of population using improved drinking water sources, total	0.11275**	0.13805***	0.10617*	0.05079
	(0.05353)	(0.04716)	(0.05939)	(0.04635)
Road density (km of road per 100 sq. km of land area)	0.05141**	0.04178	0.04260	0.13297***
	(0.02515)	(0.04398)	(0.05200)	(0.03628)
Consumer price index (2005 = 100)	-0.01500**	-0.00905	-0.02032*	-0.00654
	(0.00696)	(0.00915)	(0.01063)	(0.01186)
Population growth (annual %)	-0.00633	-0.00484	-0.01627*	-0.00686
	(0.00934)	(0.01291)	(0.00959)	(0.01765)
KOF index of overall globalization	0.10241**	0.01045	0.04040	0.20911***
	(0.04744)	(0.07020)	(0.04924)	(0.05919)
Democracy index	-0.01557	-0.04617	-0.02825	0.02541
	(0.02109)	(0.02467)	(0.03033)	(0.03485)
Dummy for fragile countries	-0.07019**	-0.08616**	-0.08324**	-0.10107**
	(0.03506)	(0.03458)	(0.03595)	(0.04270)
Dummy for low income countries (LIC)	-0.17442***	-0.20543***	-0.07751	-0.19201**
	(0.04562)	(0.06658)	(0.06029)	(0.08239)
Dummy for lower middle income countries (MIC)	-0.09049***	-0.06545***	-0.04590	-0.10996**
	(0.02972)	(0.02379)	(0.03157)	(0.04440)
Constant	-1.34578***	-0.62697	-1.04931***	-1.28960***
	(0.31975)	(0.41866)	(0.27421)	(0.36888)
Observations	237	237	237	237

Notes: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; Except HDI, EI, HI, and II (which represents the annual data at 5-year intervals), all data are average of the past 5 years' annual data (e.g., data for 2010 represents the average annual data from 2006 to 2010. However, the data of 1995 represents the average of the annual data from 1990 to 1995). All variables are in natural logarithm.

Source: UNDP's HDR database for HDI, EI, HI, and II; Dreher (2006) for KOF globalization index; Freedom House for Democracy index; UN Stats. MDGs Indicators database, available at http://unstats.un.org/unsd/mdg/Data.aspx, for access to improved water sources; and the World Bank's WDI online database, available at http://databank.worldbank.org/Data/Databases.aspx, for the rest of the variables.

The results of the other dependent variables, EI, HI, and II in columns 2, 3, and 4, respectively, are firmly consistent with the results of HDI. However, the effects of access to electricity and access to clean water sources are more significant to increase education and health indexes, whereas the road density is highly significant to increase income index. It is intuitive that electricity and clean water are more sensitive to education and health, and road is more sensitive to income.

Regarding the control variables, the results are consistent with the existing literature. The results show the significant negative impacts of consumer price index on HDI and HI, and significant positive impacts of the KOF index of globalization on HDI and II. The population growth rate is significant only at 10% to reduce the health index. Democracy index is found insignificant to all human development indexes.

Interestingly, the parameter of fragile countries dummy revealed that all the human development indexes of fragile countries are significantly lower than those of the nonfragile countries. The level of significance of such effects is 5% for all dependent variables. Thus all aspects of human development and poverty reduction progress of fragile countries largely depend on the pace of resolving conflicts and fragile situations in the subject country.

To compare the level of human development across different income groups of countries, we exclude the dummy (Or, dummies?) for upper middle income countries (UMCs) from the regression equation, the parameters of the dummies for low income countries (LICs) and lower middle income countries (LMCs) compare the level of human development and its components of LICs and LMCs with UMC. The results revealed that the level of human development is significantly lower in LMCs than in UMCs, also in LICs than in LMCs. The results are natural.

As discussed above, a dynamic panel data model can distinguish between the short-term effect and long-term effect of independent variables. For example, if we can increase access to electricity by 1% in a country at time *t*, it will increase the HDI by 0.03% in the short term because the magnitude of HDI can be estimated by using the estimated parameter of access to

electricity variable. Similarly, if we increase access to clean water sources and road density by 1%, it leads to an increase of the HDI by 0.11% and 0.05%, respectively.

At the same time, these parameters allow us to estimate also the long-run effect. According to Greene (2008, 679), the inclusion of a lagged dependent variable allow us to account for the long-term effect, which is estimated by dividing the estimated parameters of the independent variable by one minus the estimated parameter of the lagged dependent variable. In this situation, the long-term effect of access to electricity on HDI can be obtained as 0.03 / (1-0.35) = 0.05. It means that every one-percentage increase in access to electricity will increase the HDI by 0.05% over the long term, which is double that of the short-term effect.

Table 2 shows the long-term effects of all independent variables for each regression equation, and it revealed that the long-term effect of all three types of infrastructure on human development and its component indexes are far greater than short-term effects. For example, the long-term effects of access to water sources and road density on HDI are 0.19% and 0.09%, whereas the short-term effects are 0.11% and 0.05%, respectively. Similarly, the long-term effects of access to electricity, to clean water sources, and to road density on EI are 0.07%, 0.27%, and 0.08%, respectively. In fact, the results revealed that the parameters of lagged dependent variable in each regression are highly significant at 1% and positive, which means past events or information are more salient for progress on human development.

Table 2: The long-term impacts of infrastructure on human development, 1990-2010

	(1)	(2)	(3)	(4)
	Human Dev. Index (HDI)	Education Index (EI)	Health Index (HI)	Income Index (II)
Access to electricity (% of population)	0.05414	0.07057	0.06426	0.01012
Proportion of population using improved drinking water sources, total	0.18840	0.27487	0.12806	0.08680
Road density (km of road per 100 sq. km of land area)	0.08591	0.08319	0.05138	0.22723
Consumer price index (2005 = 100)	-0.02506	-0.01802	-0.02451	-0.01118
Population growth (annual %)	-0.01058	-0.00964	-0.01962	-0.01172
KOF index of overall globalization	0.17113	0.02081	0.04873	0.35735
Democracy index	-0.02602	-0.09193	-0.03407	0.04342
Dummy for fragile countries	-0.11729	-0.17155	-0.10040	-0.17272

Note: The numbers indicate the percentage change in dependent variable corresponding to a 1% change in each independent variable.
Source: The author's calculation.

These results empirically verify the key importance of infrastructure on inclusive human development in developing countries. Therefore strategic policies to provide access to infrastructure to the neediest people need to be integrated into the upcoming post-2015 development strategies. How to integrate such policies, however, is beyond the scope of this paper.

5. Conclusion

Providing access to infrastructure to the poor is essentially important for poverty reduction and inclusive development. However, only limited empirical literature on the impacts of access to infrastructure on human development is found, despite extensive policy discussion. This study reduced this gap empirically assessing the impacts of access to infrastructure services on human development. The study used system GMM as the main method to estimate the impacts, which revealed that the selected three infrastructure variables, access to electricity, access to clean drinking water sources, and road density, all have significant positive impacts on HDI. In the

situation of component indexes of HDI as dependent variable, access to electricity and access to clean water sources have positive and significant effects only on education and health indexes. On the other hand, road density is highly significant to increase the income index. It clearly indicates the key importance of water and energy access to health and education and transport infrastructure on the income aspects of human development.

These results can serve as important references for policy makers while designing policies for poverty reduction and inclusive development. If the people or areas lack access to basic infrastructure services, connecting people to the basic infrastructure, such as energy, clean water sources, and transportation services, can be the first step to poverty reduction and inclusive development. This is more relevant in the context of expiring MDGs and the ongoing global process of formulating post-2015 new-development strategies. Thus further study is suggested to learn the proper ways to incorporate the access to infrastructure on post-2015 development goals.

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Appendix 1. List of the countries included in the data analysis

1	Albania	32	Guinea	63	Pakistan
2	Argentina	33	Guinea-Bissau	64	Panama
3	Armenia	34	Guyana	65	Paraguay
4	Azerbaijan	35	Honduras	66	Peru
5	Bangladesh	36	India	67	Philippines
6	Belarus	37	Indonesia	68	Romania
7	Belize	38	Iran, Islamic Rep.	69	Russian Federation
8	Bhutan	39	Jamaica	70	Rwanda
9	Bolivia	40	Jordan	71	Senegal
10	Brazil	41	Kazakhstan	72	Serbia
11	Bulgaria	42	Kenya	73	Seychelles
12	Burkina Faso	43	Kyrgyz Republic	74	Sierra Leone
13	Burundi	44	Lao PDR	75	South Africa
14	Cambodia	45	Latvia	76	Sri Lanka
15	Cameroon	46	Lesotho	77	Sudan
16	Central African Republic	47	Lithuania	78	Swaziland
17	Chile	48	Macedonia, FYR	79	Syrian Arab Republic
18	China	49	Madagascar	80	Tajikistan
19	Colombia	50	Malawi	81	Tanzania
20	Costa Rica	51	Malaysia	82	Thailand
21	Cote d'Ivoire	52	Mali	83	Tunisia
22	Dominican Republic	53	Mauritania	84	Turkey
23	Ecuador	54	Mexico	85	Uganda
24	Egypt, Arab Rep.	55	Moldova	86	Ukraine
25	El Salvador	56	Morocco	87	Uruguay
26	Ethiopia	57	Mozambique	88	Venezuela, RB
27	Fiji	58	Namibia	89	Vietnam
28	Gambia, The	59	Nepal	90	Yemen, Rep.
29	Georgia	60	Nicaragua	91	Zambia
30	Ghana	61	Niger		
31	Guatemala	62	Nigeria		

Appendix 2. Summary Statistics

Variables	Obs.	Mean	Std. Dev.	Min.	Max.
Human Development Index (HDI)	364	0.555	0.152	0.206	0.805
Education Index (EI)	364	0.523	0.190	0.092	0.883
Health Index (HI)	364	0.694	0.157	0.165	0.934
Income Index (II)	364	0.482	0.137	0.171	0.738
Access to electricity (% of population)	364	61.282	36.920	1.5	100
Proportion of population using improved drinking water sources, total	364	78.108	18.415	16.7	100
Road density (km of road per 100 sq. km of land area)	364	30.321	35.724	0.5	201
Consumer price index (2005 = 100)	364	77.821	37.940	0.004	172.664
Population growth (annual %)	364	1.610	1.183	-1.575	5.294
KOF index of overall globalization	364	46.558	12.453	14.983	77.438
Democracy index	361	3.987	1.331	1	7

Appendix 3. Correlation Matrix

Variables	HDI	ele	water	road	CPI	pop	gobl	demo
Human Development Index (HDI)	1							
Access to electricity (% of population) [ele]	0.90	1						
Proportion of population using improved drinking water sources, total [water]	0.81	0.78	1					
Road density (km of road per 100 sq. km of land area) [road]	0.28	0.24	0.30	1				
Consumer price index (2005 = 100) [CPI]	0.20	0.15	0.16	0.07	1			
Population growth (annual %) [pop]	-0.03	-0.04	0.02	-0.07	-0.04	1		
KOF index of overall globalization [gobl]	0.71	0.62	0.62	0.14	0.42	-0.17	1	
Democracy index [demo]	-0.45	-0.29	-0.36	-0.23	-0.20	-0.09	-0.57	1

Abstract (in Japanese)

要約：

人間開発にインフラが与える影響をめぐり、これまで政策議論が活発に行われてきたものの、実証的な先行研究は乏しかった。また、インフラは国連ミレニアム開発目標（MDGs）達成への原動力であるという固いコンセンサスは見られるものの、交通やエネルギーといった主要なインフラサービスは、現行の MDGs に含まれていない。

本論文は､1995 から 2010 年までの期間の 91 の途上国を対象にしたパネルデータを用いて、インフラ変数（電力へのアクセス、きれいな飲み水へのアクセス、道路密度）が人間開発指標（HDI）および３つの構成変数（保健、教育、所得）にあたえるインパクトの計測を試みている。一般モーメント法（GMM）の動的パネル推計を行ったところ、３つのインフラ変数全てが HDI に対し有意な正のインパクトが認められた。しかしながら、電力へのアクセスときれいな飲み水へのアクセスは、教育及び保健指標に対してのみ、有意な正のインパクトが確認された。他方、道路密度に関しては、所得指標を押し上げる有意な効果が確認された。

これらの分析結果から、あらゆるインフラサービスへのアクセスの欠如、いわゆるインフラ貧困を撲滅することは、持続的な人間開発への必要条件であり、２０１５年以降の新たな開発戦略において、インフラ貧困を巡る課題を包括的に取り組むことが重要であるといえる。

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